Use of a Self-Cleaning Sensor for In-Tank Continuous Viscosity and Density Monitoring of Ceramic Slurry

by Rheonics GmbH

Background

Monitoring the density and viscosity of slurry is critical for shell building in investment casting. In many shell rooms, this is achieved through a combination of manual and laboratory measurements. Tools such as efflux cups, viscometers, densitometers, pycnometers, cylinders, and flasks are commonly used to maintain uniform slurry properties. However, these measurement methods have inherent challenges that can impact accuracy and efficiency.

The formation of deposits in shell casting is the intended outcome, but it also presents challenges in maintaining consistent measurement data. This issue affects both on-line and off-line measurements. In-tank sensors, such as the Rheonics SRD viscometer, can be used for monitoring slurry properties. In many cases, the sensor functions effectively without interference. However, in slurries prone to deposition, sensor cleaning becomes necessary to maintain accuracy. The presence of shell-like deposits on the sensor can cause viscosity and density readings to increase.

Manual measurements are subject to various sources of error. They are intermittent, influenced by operator variability, and often time-consuming due to the frequent cleaning of measurement devices. Additionally, the time delay between sample collection and obtaining readings can hinder process efficiency.

The frequency of required cleaning for in-tank sensors determines how hands-on the operators must be to ensure continuous viscosity and density readings. Because different slurries require different cleaning frequencies, it is difficult to establish a standardized cleaning schedule. Observing readings over time is necessary to determine the appropriate cleaning frequency, and varies even between tanks within the same facility. The variability in cleaning requirements and development of the cleaning schedule can pose a significant hurdle to operators integrating viscosity measurements into process control systems.

Given these challenges, there is a clear need for a method to prevent deposition and maintain accurate, continuous viscosity and density measurements in slurry environments.

Motivation

The objective is to develop a sensor that provides continuous viscosity and density readings without requiring frequent cleaning. This could involve either preventing deposit formation or enabling the sensor to remove deposits after they form. Such a solution would reduce operator workload, minimize maintenance, and improve confidence in the measurements.

Various approaches have been considered to achieve

Photo licensed by Adobe Stock

this goal. One suggestion was to implement a standardized cleaning schedule. However, differences in slurry composition, tank conditions, and facility operations make this approach impractical. Another option was to use cleaning robots, but for some types of deposits, these systems would not act quickly enough to maintain clean sensors for continuous readings. Non-stick coatings were also explored, but due to the abrasive nature of slurries, these coatings degrade quickly. The solution described here was the development of a self-cleaning sensor.

A self-cleaning sensor must be capable of either preventing or removing deposits once they form. It must also be compatible with existing sensor technology and should not introduce unnecessary complexity. For investment casting applications, it is essential that the sensor does not interfere with the dipping of wax trees.

Design Principle

Taking inspiration from a wet dog shaking off water, cleaning vibrations were added to the sensor. This led to the development of our SlurrySense device. A low frequency, high amplitude vibrational unit is built-in to mimic the water-shedding motion observed in dogs. The SlurrySense also features an adjustable mounting system that allows the sensor's depth in the tank to be modified. This device adds vibrational cleaning to the Rheonics SRD viscosity and density sensor to provide continuous slurry property measurements.

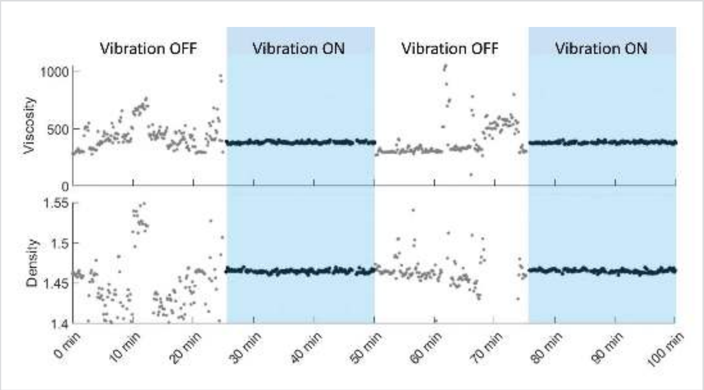

Figure 1: Stable readings were achieved with vibration during validation experiments.

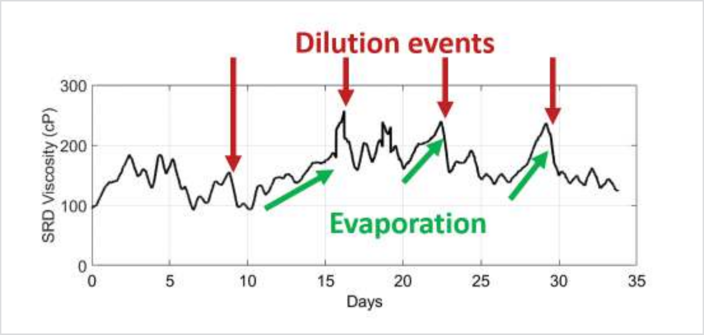

Figure 2: Sample measurement data for SlurrySense operation during a 1-month period without cleaning

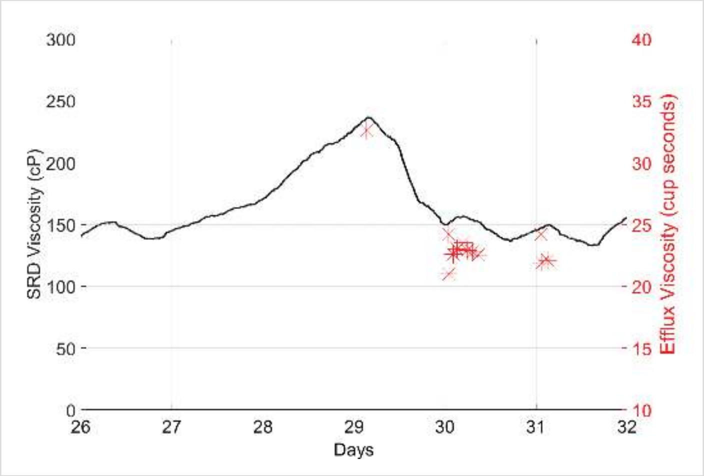

Figure 3: Representative SlurrySense measurements for a slurry plotted alongside representative efflux measurements.

Proof of Concept

To validate our device, testing was performed with both intermittent and continuous vibration. This experiment was performed using a rotating bowl mixer with a plow blade. We used a 5 L bowl containing SuspendaSlurry FS (Ransom & Randolph) that was continuously rotated, both with and without the vibration activated. The vibrator in this design is pneumatically operated. Viscosity and density were recorded over time, with cleaning vibrations alternating between 25 minutes off and 25 minutes on. The experimental data (see **Figure 1**) confirmed that when the vibration was off, viscosity and density readings fluctuated. However, with vibration, the readings stabilized. This demonstrates that the selected frequency and amplitude do not interfere with measurement accuracy. Furthermore, the vibrating self-cleaning viscosity and density sensor provided stable and repeatable measurements. A manual density check was performed to ensure that the low-frequency cleaning vibrations did not affect measurement accuracy.

Field Trial

For additional validation, field trials were conducted in operating shell rooms. SlurrySense sensors have been running continuously without deposits forming on the sensors. Plant operations continued normally: data was acquired using efflux cups and the SRD in parallel.

Sample data from field trials (see **Figure 2**) show that the sensor could detect evaporation events over weekends and holidays, as well as dilution events, which appear as drops in viscosity. Throughout one month of operation, no cleaning or inspection was required to maintain sensor accuracy. Additionally, density measurements remained consistent over the same period. These results confirm that our sensor provides accurate data, and when compared with efflux cup measurements from the same facility, the viscosity trends observed with the SRD sensor aligned with those recorded by the efflux cup (see **Figure 3**).

Figure 3 demonstrates that after a period of evaporation, both the efflux cup and SRD viscosity measurements were elevated. Once water was added, the viscosity readings from both methods dropped accordingly. This confirms that the SRD viscosity measurement is capable of following efflux cup trends and can be used for process control, even in deposit-prone slurries.

Conclusion

In summary, we have successfully developed a self-cleaning sensor that prevents deposit formation while maintaining compatibility with existing sensor technology. The vibration of the viscometer and density meter operates simultaneously with the continuous readings with reliable data. Field trials have demonstrated that it does not disrupt tree dipping operations and remains deposit free in deposit prone slurries.

Outlook

The outlook for the SlurrySense in shell room viscosity and density control is promising. This self-cleaning technology extends the application of the Rheonics SRD sensor into deposit-prone slurries without excessive cleaning requirements. It reduces reliance on manual measurements and minimizes cleaning time for operators. Furthermore, the reassurance that the device remains clean increases trust in in-tank viscosity and density measurements, aligning well with efflux cup readings, dilution events, and evaporation observations.